N90-25515

CREW CHIEF: A COMPUTER GRAPHICS SIMULATION OF AN AIRCRAFT MAINTENANCE TECHNICIAN

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ABSTRACT

Approximately 35% of the lifetime cost of a military system is spent for maintenance. Excessive repair time is caused by not considering maintenance during design. Problems are usually discovered only after a mock-up has been constructed, when it is too late to make changes. CREW CHIEF will reduce the incidence of such problems by catching design defects in the early design stages. CREW CHIEF is a computer graphic human factors evaluation system interfaced to commercial CAD systems. It creates a three dimensional man model, either male or female, large or small, with various types of clothing and in several postures. It can perform analyses for physical accessibility, strength capability with tools, visual access, and strength capability for manual materials handling. The designer would produce a drawing on his CAD system and introduce CREW CHIEF in it. CREW CHIEF's analyses would then indicate places where problems could be foreseen and corrected before the design is frozen.

INTRODUCTION

CREW CHIEF is a computer graphics model of a maintenance technician. This model, interfaced to existing commercial CAD systems used by aerospace manufacturers, may assist in evaluating the maintainability of Air Force aircraft as well as equipment in general. CREW CHIEF is an expert system which enables the designer to perform the functions of an expert ergonomist. The CREW CHIEF model allows the designer to simulate a maintenance activity using the computer-generated design as a 3-D mockup to determine if the required maintenance activities are feasible. CREW CHIEF is a large program, with a core of more than 500 subroutines containing over 120,000 lines of code. Version 1 of the CREW CHIEF model was completed in April 1988, and has been distributed to major DoD contractors.

Since CREW CHIEF is interfaced to existing commercial CAD systems used by aerospace manufacturers, the program does not require users to transfer the system or equipment design into the CREW CHIEF program for analysis; rather, CREW CHIEF is called into the user's drawing without any conversion.

The CREW CHIEF model provides for the designer the ability to simulate, on the computer-aided drawing board, maintenance and other related human operator interactions with a system. It creates a model of the correct body size and proportions of both male and female maintenance technicians, the encumbrance of clothing and personal protective equipment (PPE), mobility limitations for simulating working postures, physical access for reaching into confined areas (with hands, tools, and objects), visual access (evaluating what the CREW CHIEF can see), and strength capability (for using hand tools and manual materials handling tasks).

The CREW CHIEF user can select from a range of body sizes of male and female technicians. CREW CHIEF will generate 1st, 5th, 50th, 95th, and 99th percentile body sizes for male and female maintenance technicians. During a CREW CHIEF run, at selected points in the program, the user can select other genders and body sizes to be used in further analyses.

CREW CHIEF automatically considers the encumbrance of clothing and PPE, a very important limitation for the maintenance technician. The initial model has four types of standard clothing to choose from: fatigues, cold weather, arctic, and chemical defense. The clothing types add encumbrance to the joint mobility limits when the human-model performs reaches. The program

adjusts the posture to one used in maintenance activities, and analyzes the accessibility considering the clothing type selected.

The model automatically plots the workplace from the CREW CHIEF human-model's viewpoint to evaluate visual accessibility, showing appropriate obscuration of gear worn on the head. The visibility plot allows the designer to see the task from the maintenance technician's viewpoint to verify visual accessibility. Both a CRT presentation and a hard copy plot are available.

To simulate the body postures typical in maintenance, CREW CHIEF provides twelve starting postures: standing, sitting, kneeling on one knee, kneeling on both knees, bending, squatting, lying prone, lying supine, lying on the side, walking, crawling, and climbing. Some of these postures reduce the mobility and strength available to perform the task. The designer should initially select the most appropriate posture, and then he/she can manipulate all the body segments to change a posture to make it fit the situation. Automated evaluations of accessibility, reach, and strength analyses can be performed in each of these postures.

The CREW CHIEF program computes the strength capabilities of the maintenance technician based on gender, posture, and the task performed. CREW CHIEF computes strength for manual materials handling tasks (lifting, carrying, holding, pushing, and pulling), applying torque to bolts using wrenches, and connecting /disconnecting electrical connectors. More than 100,000 strength measurements were conducted to develop the strength analysis models in CREW CHIEF.

Accessibility analysis capabilities include the ability of the human-model to reach and operate any tool or object. The object, an electronics box for example, may already be part of the design. The CREW CHIEF program has 105 common hand tools to evaluate reach and accessibility. These were modeled from the tools available in Air Force maintenance technicians' tool boxes. By providing the designer a set of common tools for evaluation, the need for special tools will be reduced. The designer chooses the tool to be used and, depending on the tool, there may be one or several methods of holding the tool in the hand.

The CREW CHIEF model is three-dimensional. To accurately represent clothing, the model has a surface of thousands of triangular facets attached to the 35 links of the skeletal link system. The designer may select the simplified 3-D model when rotating the workplace on the display and a higher resolution 2-D profile projection for plots. The user may also produce on-screen shaded surface pictures from this model.

The largest single effort in the development of the CREW CHIEF human-model was gathering the research data. The CREW CHIEF human-model is a simulation of the physical characteristics and limitations of the maintenance technician. The development of this simulation requires an extensive and accurate data base describing those characteristics and limitations.

CREW CHIEF has been provided to government contractors. Later, it will be available to other industries. The software is available without charge, but users must have the appropriate computer hardware and software. At present, CREW CHIEF Version 2 with a common core has been interfaced to the following host CAD systems:

- CREW CHIEF Host-Independent (unhosted core of CREW CHIEF) FORTRAN 66 and FORTRAN 77.

- CREW CHIEF-CADAM Version 20 with Geometry Interface Module for MVS/SP operating system, FORTRAN 66H.

- CREW CHIEF-CADAM Version 21 with Interface User Exit (IUE) for MVS/SP operating system, VS FORTRAN 66 and 77, and for VM/IS operating system, FORTRAN 77H Extended.

- CREW CHIEF-Computervision Version CADS 4001 with an Analytical Processing Unit (APU) and CADDS 4X software, revision 5B or later.

- CREW CHIEF-Computervision CADDStation Version for UNIX operating system.

In addition to the previously described access, strength, and visibility analyses, work is currently underway on two more capabilities for CREW CHIEF. First, a Task Time Estimator will be added. While a large body of knowledge exists concerning performance times on various actions, a well known example being MTM or Methods Time Measurement, these typically are actions performed under fairly benign conditions. In aircraft maintenance, the technician frequently has to work under rather severe constraints. e.g., in a prone position, in hard to reach and invisible locations, in heat and cold, and while wearing protective clothing, to name a

few. Conditions like these prolong performance times. When completed, the Task Time Estimator will be able not only to predict the basic performance time but also by how much the time will be prolonged because of the various detriments discovered during the analyses.

The other future undertaking is to model an astronaut, wearing a space suit, and working under microgravity conditions. Two things are immediately obvious: one, strength data from one G will be largely invalid, and two, the mobility of the astronaut is very much determined by the design of the space suit. To gather strength data, an initial experiment has been conducted under water to simulate microgravity. Still large amounts of work remain to be done before the data are of a sufficient quantity to be usable. While much of the work will be done under water, it may possible to gather some under actual orbital conditions.

Modeling the astronaut's mobility will require studying and measuring the design of the space suit. The directions and magnitudes in which a space suit can move will be the limiting factors in this case. Also, the strength needed to move the space suit will have at least some effect on the available strength of the astronaut. There may be postures, possible under microgravity, that are are impossible to attain on earth. While the final decision on this has not been made, it is conceivable that the space program will not be part of CREW CHIEF but will be an independent and separate program. Otherwise, the result may be a program that is just too unmanageably large.

REFERENCES

Korna, Medhat, et al, "User's Guide for CREW CHIEF: a Computer Graphics Simulation of an Aircraft Maintenance Technician," AAMRL-TR-88-034, Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1988.